Massachusetts Institute of Technology
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Cambridge, Massachusetts

LUMINARY Memo #160

To: Distribution
From: David Moore
Date: 16 July 1970
Subject: Descent Trajectory Monitor Package

Summary:

The LMS at KSC has asked for a comparison of the Descent Trajectory Monitor Chart between that supplied by MPAD (LM Timeline Book, 2/16/70) and that supplied by MIT all digital simulation data (Luminary 1D-level 4-Lunar Landing). The package is included in the memo and has been sent to KSC for verification on the LMS.

Purpose:

Ascertain reason for apparent difference in VI, $\dot{H}$, and H during descent as monitored on LMS/KSC and compared with MPAD/LM Timeline data.

Test:

Obtain nominal all-digital simulation, plot VI, HDOT, H with VI, $\dot{H}$, H from MPAD/LM Timeline vs. Time in Powered Descent. Ascertain curve relationship of each curve (if curves coincidence, the data corresponds; if curves parallel, the data corresponds). The curves are on Figures 1, 2 and 3.

Results:

The curves are seen to be essentially parallel in that a general shape pattern is followed. The maximum error evident from the plots is:

VI (Figure 1)	- 3%
H (Figure 2)	-2%
HDOT (Fig. 3)	-10%

The greatest difference in the HDOT curves is 10%; however it is noticed that the general curve shape of each curve is approximately the same. The curves converge at throttle down and at higate and otherwise follow a pattern of essentially the same shape. The VI and H curves differ only slightly.

Data was also available from LM TIMELINE BOOK (3/16/7) and included in the plots of Figures 4, 5, and 6. These curves are similar to those of Figures 1, 2 and 3 in that a general shape pattern is also followed.

For both sets of LM TIMELINE data, the curves are of the same faimily; in that, if f(V), f(HDOT), f(H) are the trajectory curves as plotted; f_1 is MIT data, f_2 is MPAD data: Then

$$f_2(V) = f_1(V) + C_V$$

$$f_2(HDOT) = f_1(HDOT) + C_{HDOT}$$

$$f_2(H) = f_1(H) + C_H$$

where each C is a constant by which the curves of Figures 1-6 differ.

This means that a percentage error plot should tell that the curves do not converge; i.e., the C in the equations does not vary along the trajectory. If the C does vary, however, the curves will converge and the percentage error will be small at the points of convergence. For example in Fig. 1, $C_V \approx 200$ so that the percentage error at 4500 fps is less than that at 1000 fps. The C in that case does not vary as the curves plainly show no convergence. On the other hand, Figure 3 implies a varying C_{HDOT} along the curve which is evidenced by the convergence of the curves at T=390 (throttle-down) and T=480 (HIGATE).

Conclusion:

Readily apparent from the plots is the fact that the initial state of all sets of data closely agree. However, it is not so apparent what trajectory information was given to the simulated AGC so that the curves in Figures 1-6 resulted. Possible differences include:

A. Terrain model difference

B. Trajectory target parameter difference.

The main conclusion is that KSC/LMS should use the MIT/DL all-digital simulation initialization included in this memo to ascertain possibility of

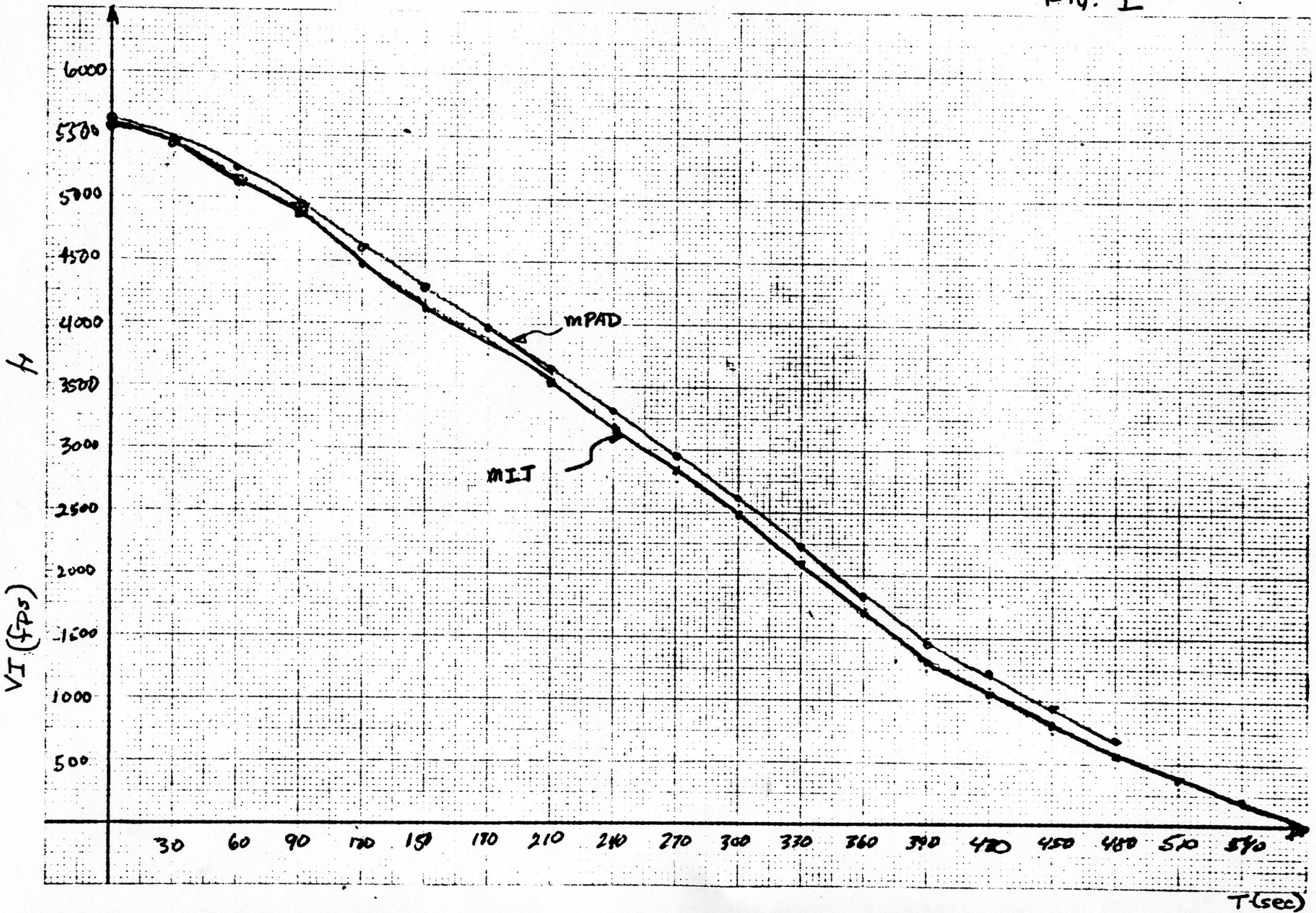
agreement between simulations. Failure of agreement between LMS/KSC and MIT then would open questions as to consistency of simulations. Agreement between the simulators would imply inconsistent initialization and communication of the correct data would be encouraged.

VI VS TIME IN POWERED DESCENT

—o— = MIT ALL-DIGITAL

—o→ = MPAD LM TIMELINE (2/16/70)

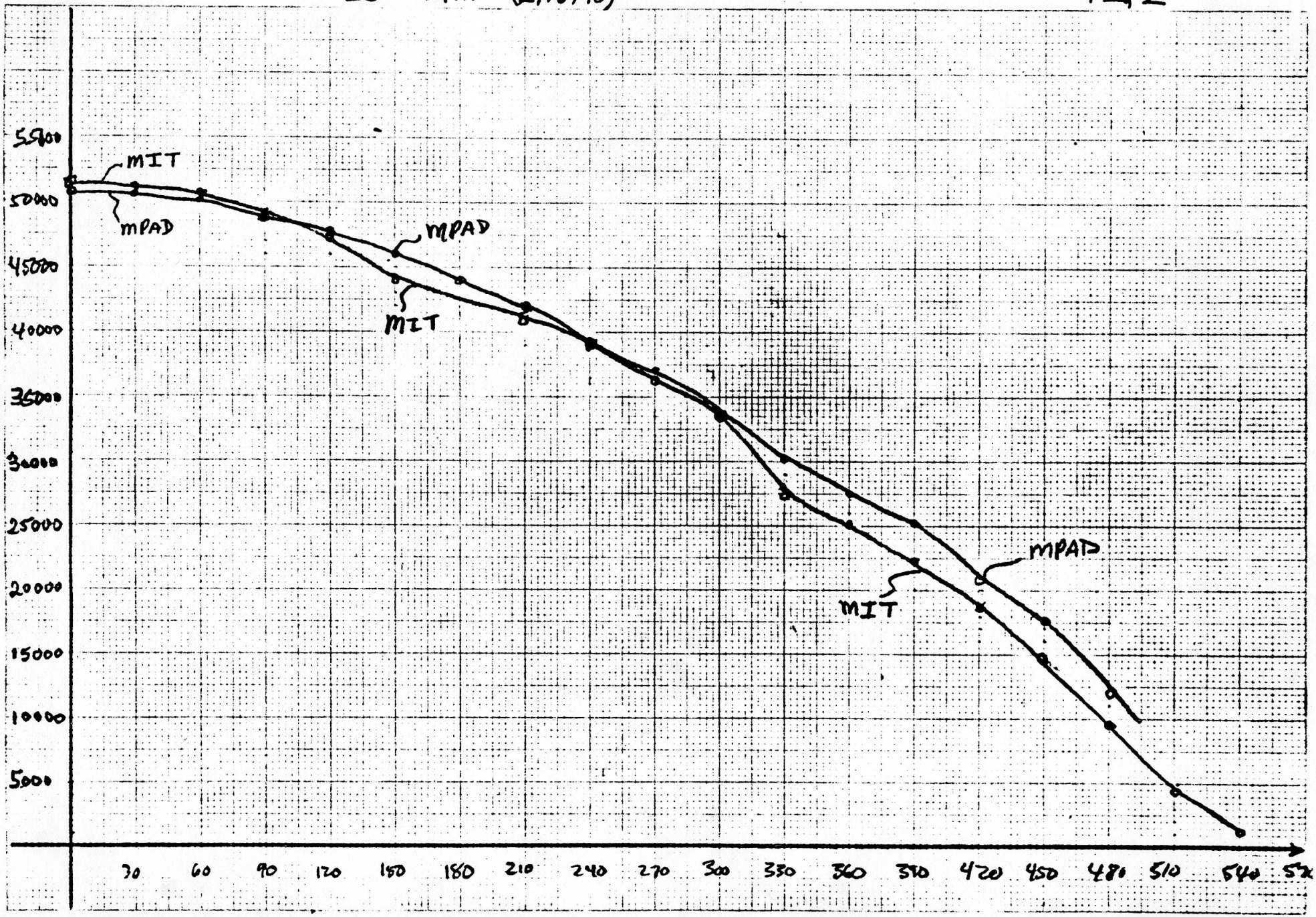
FIG. 1



H vs TIME IN POWERED DESCENT

MIT
MPAD (2/16/70)

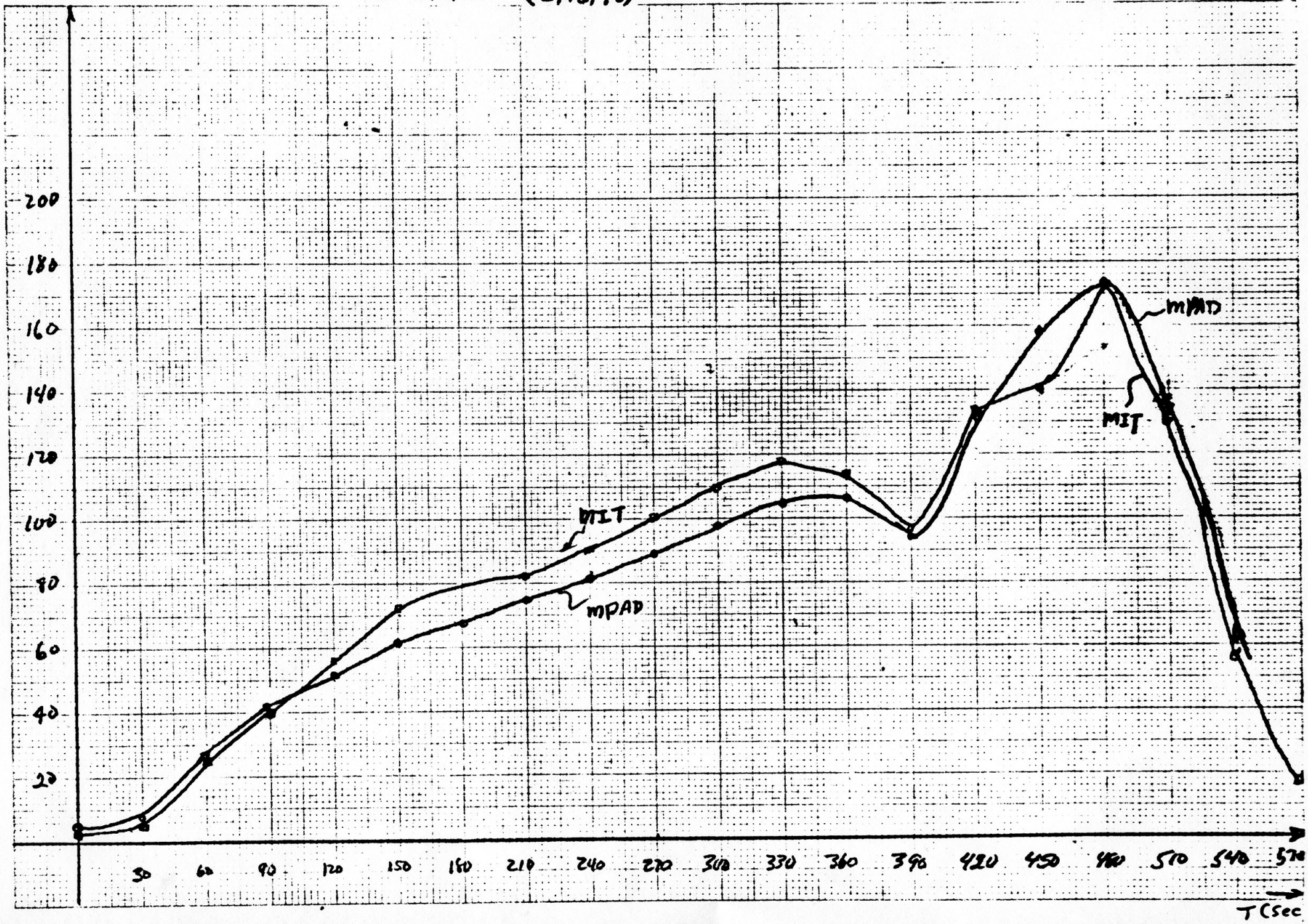
FIG 2



HDOT VS TIME IN POWERED DESCENT

- MIT
⊖ - MPAD (2/16/70)

FIG. 3

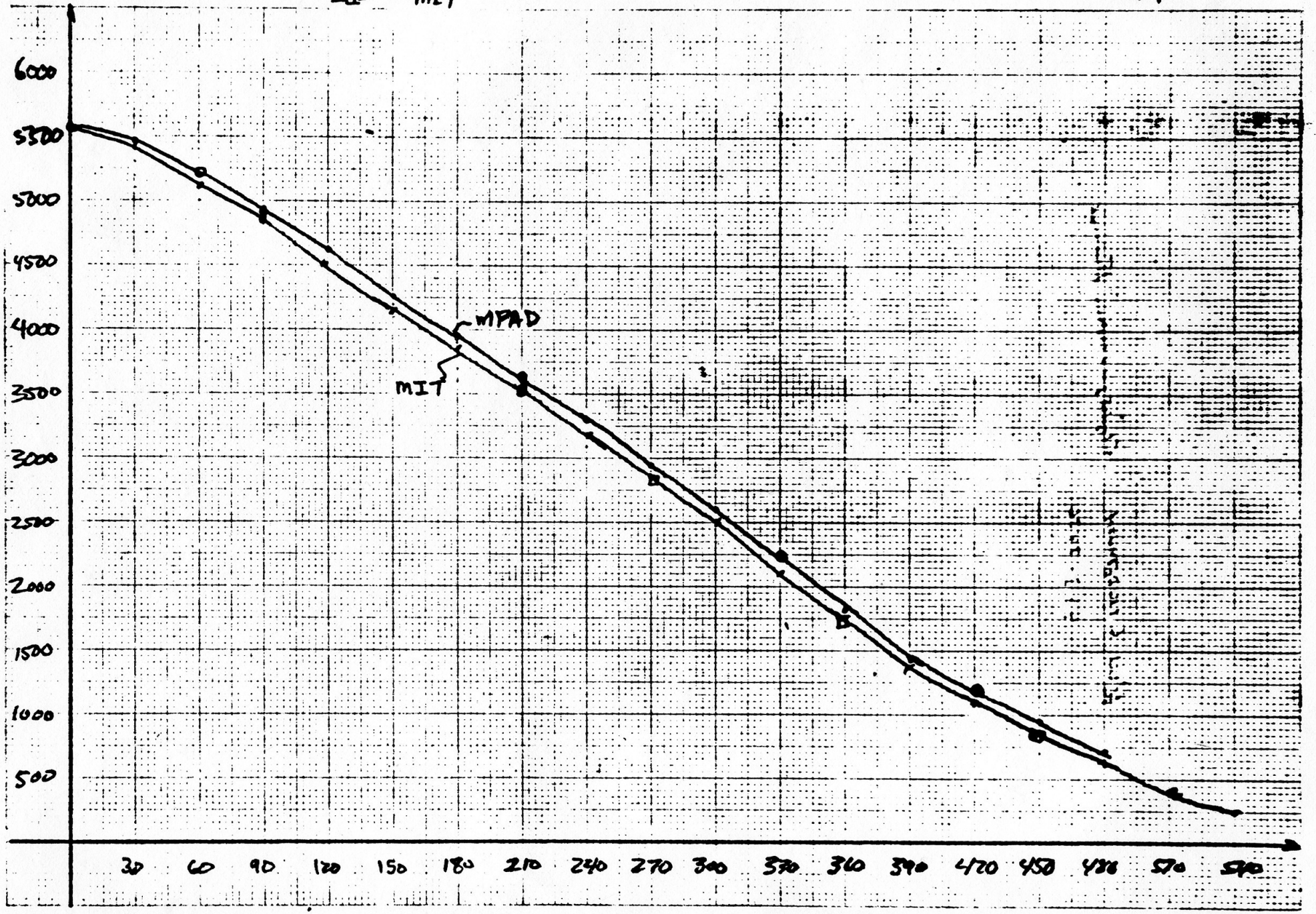


VI vs TIME IN POWERED DESCENT

-o- - MPAD (3/16/70)

-□- - MIT

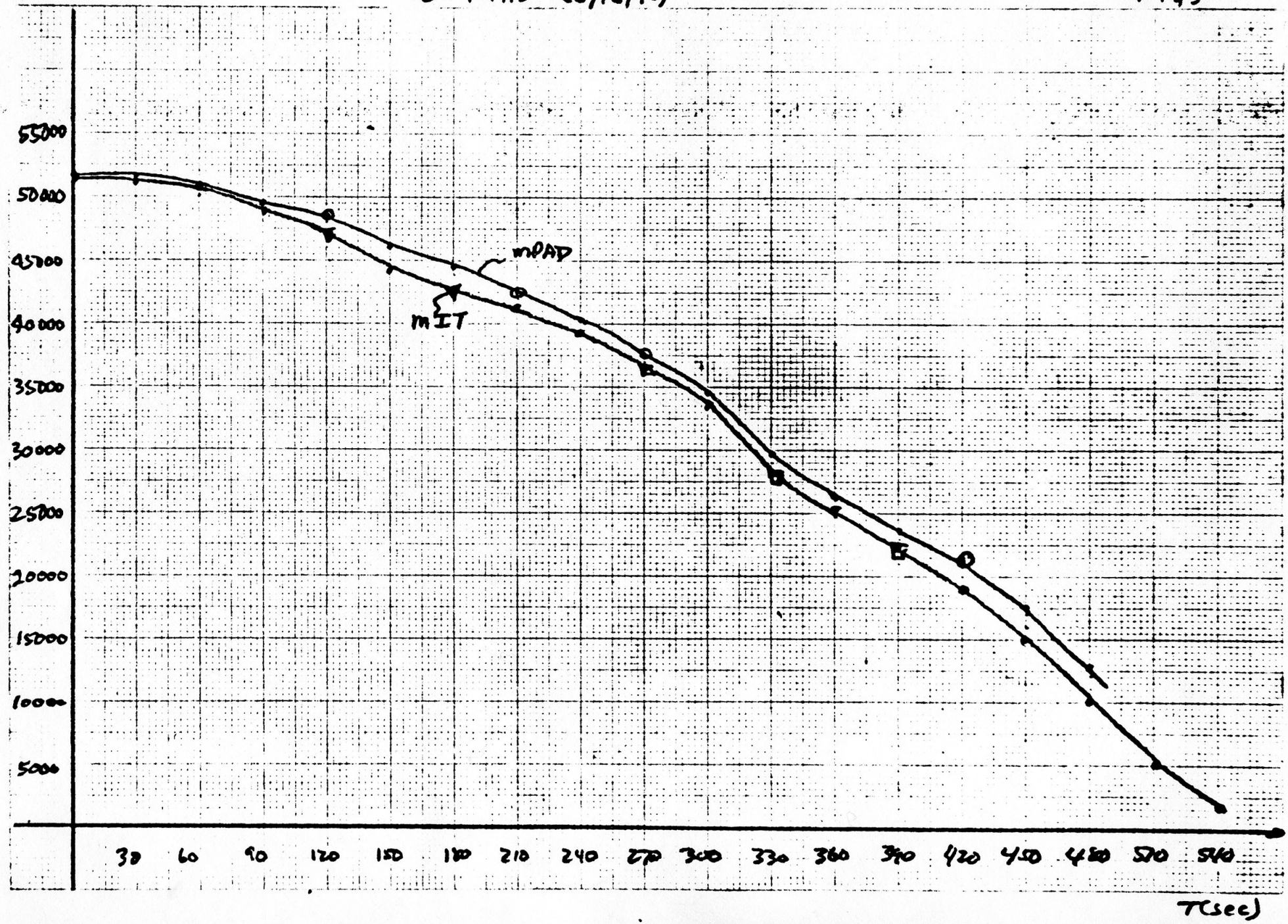
Fig 4



H vs TIME POWERED DESCENT

-□- MIT
-o- mPAD (3/16/70)

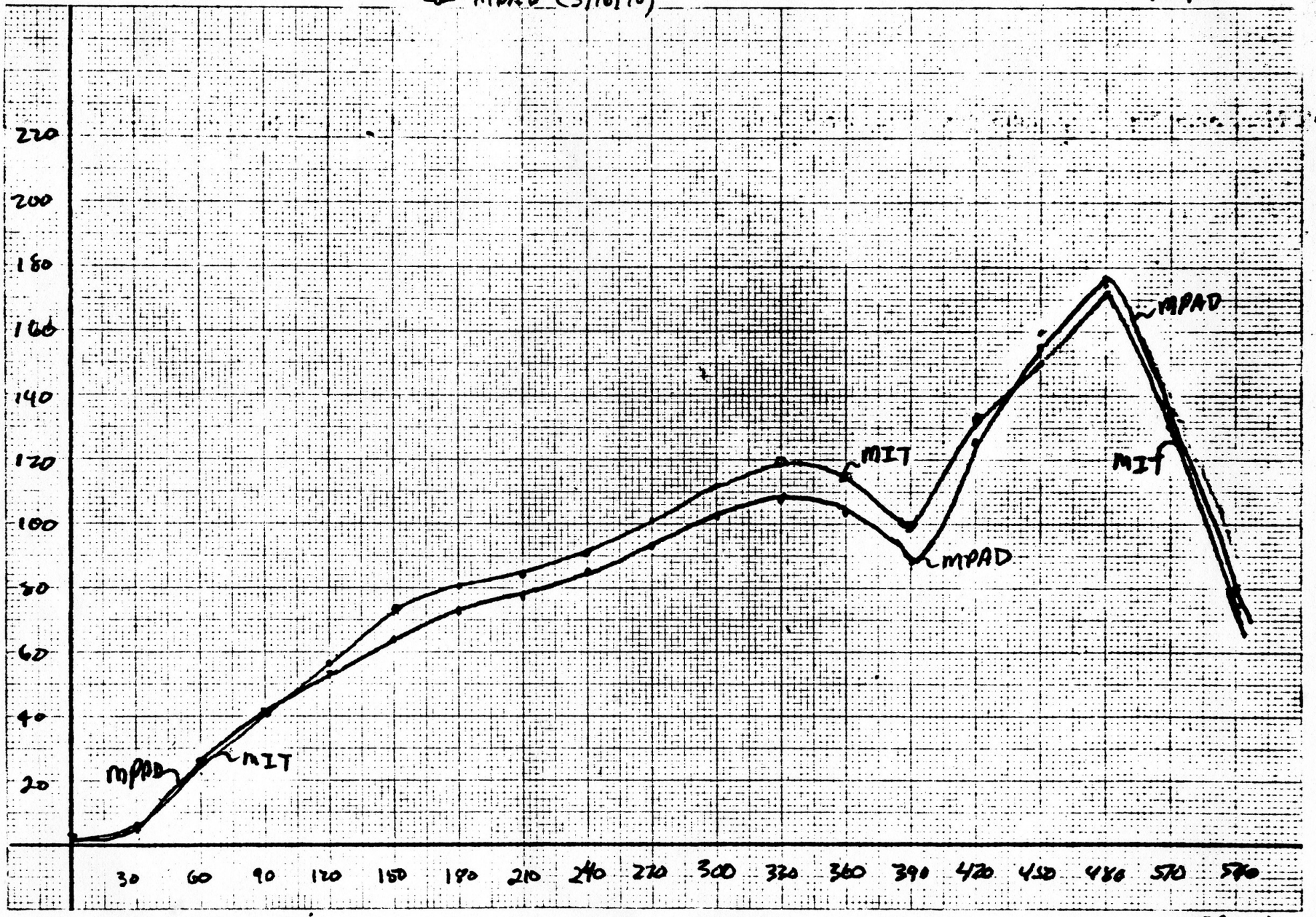
FIG 5



HDOT VS TIME IN POWERED DESCENT

MIT MPAD (3/16/70)

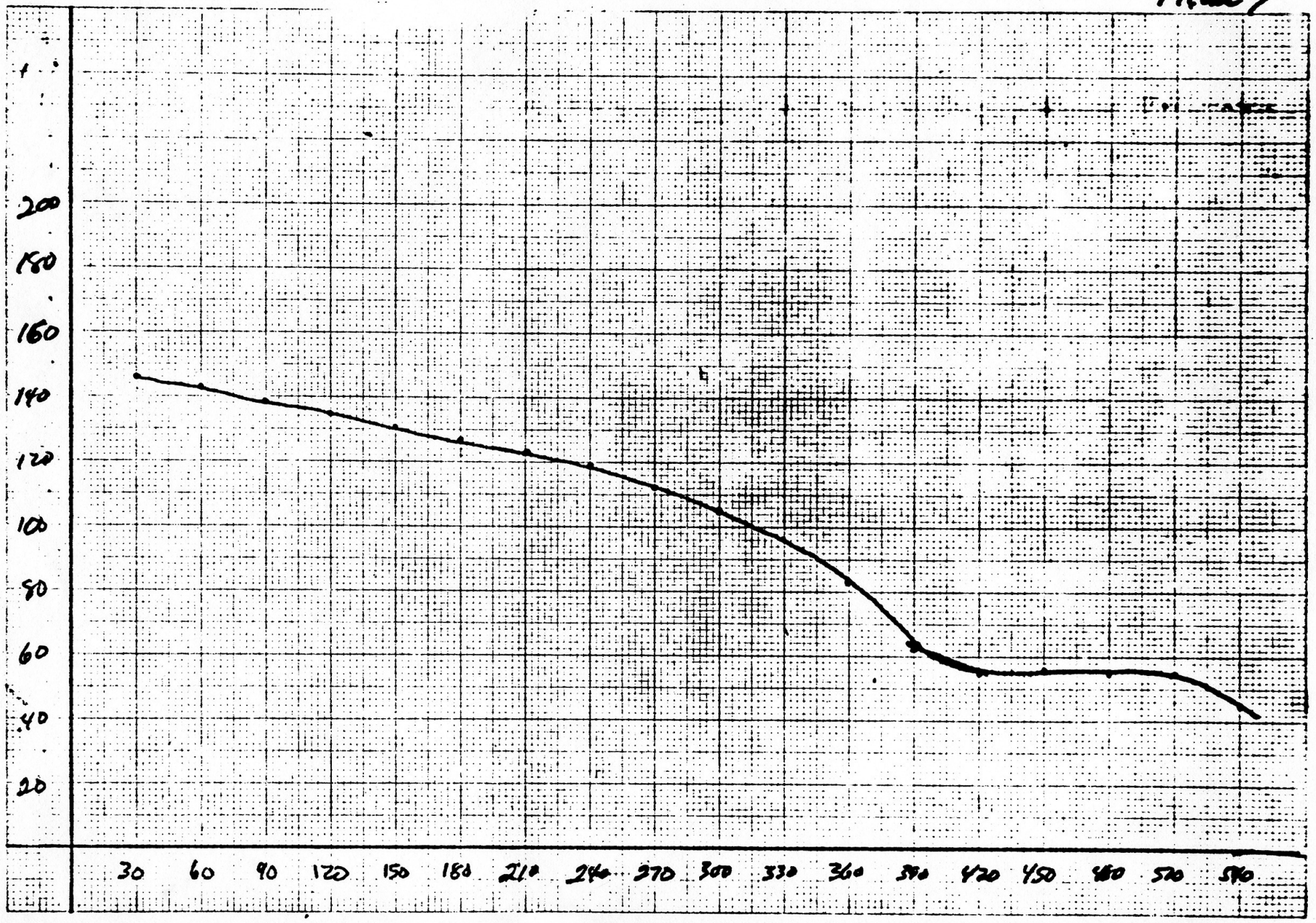
FIG 6.



11 Graph

7. THRUST VS TIME IN POWERED DESCENT

FIGURE 7



DESCENT TRAJECTORY MONITOR PACKAGE

The following package contains

A. DESCENT TRAJECTORY TIME CHART
B. ERASABLE PADLOAD
C. INITIALIZATION EDIT (ENV. vs. AGC)
D. ASTRONAUT FILE
E. EVENT LIST

DESCENT TRAJECTORY TIME CHART

T(from TIG)	V	$\dot{H}$	H	MODE
0	5558.3	-2.9	51457	63
30	5478.9	-5.0	51387	
60	5193.9	-25.1	50905	
90	4900.2	-40.1	49920	
120	4496.0	-55.8	47989	
150	4183.4	-73.7	44084	
210	3532.0	-82.1	41743	
240	3191.7	-90.7	39150	
270	2840.3	-100.1	36627	
300	2476.1	-111.9	33826	
330	2099.7	-118.7	27838	
360	1711.2	-113.9	25100	
390	1308.8	-97.4	22254	
420	1059.5	-134.1	18915	
450	818.6	-160.5	14632	
480	575.7	-173.7	9777	
510	364.6	-135.6	4761	64
540	232.9	-57.6	1674	
570	132.2	-18.8	641	
600	56.2	-6.3	294	
630	6.7	-3.5	141	
660	0	-1.3	66	66
690	0	-1.3	20	66

DESCENT TRAJECTORY

PDI THRU TD+3 MIN

RESET WATCH
-1:00 MASTER ARM-ON
- :30 ENG ARM-DES
- :07.5 ULLAGE
- :05 PRO
+ :00 PDI
+ :02 (NO IGN) - START PB - PUSH

+ :05 DES ENG OVRD -ON
MASTER ARM-OFF
+0:26 THROTTLE UP
√T/W > 1.6

V21N69

V57E - (+) LR HIGHER THAN LGC PRO TO PERMIT LR DATA

✓ ED BATTS

N68
223+00060 (DO NOT ENTR)

SEQ CAMR - ON

θ	TFI	VI	(-HMAX) -HDOT	(ΔH) H	DPS	SBD P/Y
110	0:00	5562.0	3.8	50700	100	-2/2
109	0:30	5492.0	6.0	50595	99	
104	1:00	5205.1	25.4	50111	93	2/-2
98	1:30	4909.9	40.2	49116	88	
94	2:00	4606.7	51.2	47738	83	10/-9
90	2:30	4295.5	60.0	46064	77	
86	3:00	3976.3	67.5	44151	72	15/-14
83	3:30	3648.3	74.5	42020	67	
81	4:00	3310.8	81.7	39675	61	19/-18
79	4:30	2962.9	89.5	37007	56	
				(+17000)		
77	5:00	2603.5	97.4	33795	51	23/-21
				(+15600)		
75	5:30	2231.6	104.1	30329	45	
				(+13500)		
72	6:00	1846.9	105.4	27542	40	26/-24
				(+11800)		
70	6:30	1449.7	93.8	25071	35	
			(434.6)	(+ 9800)		
66	7:00	1209.8	134.1	21962	32	32/-28
			(388.8)	(+ 7600)		
64	7:30	969.5	159.9	17928	28	
			(321.0)	(+ 6000)		
60	8:00	726.5	173.3	12704	25	37/-31

P64

223E @ 6K

P64 + 15 SEC:
NO THROTTLE DN
- ABORT

523 ALARM
V58
PRO
RESET
LDG ANT-HOVER

PGNS MODE CONT-
ATT HOLD

P66

X-PNTR-LO MULT

BINGO FUEL
DES QTY LT+1+34

TOUCHDOWN

ENG STOP - PUSH
PRO
MODE CONTROL (BOTH) - AUTO
DES ENG CMD OVRD - OFF
ENG ARM - OFF
413 + 1

RECYCLE PARKER VALVE

H	(-Ḣ MAX) -H DOT)	DPS	LPD TERR CORR
7000	(228.2) 165.0	22	(TBD)
5000	(186.9) 134.4	20	
4000	(163.2) 110.9	20	
3000	(136.3) 85.8	19	
2000	(104.6) 52.4	17	
1000	(63.8) 28.0	15	
500	(35.7) 18.5	14	
400	(28.7) 16.0	13	
300	(21.0) 12.8	12	
200	(12.2) 9.7	12	

ABORT STAGE - PUSH
ENG ARM - ASC
ENG STOP - RESET
ENG START - PUSH
MODE CONTROL(2)- AUTO

PDI THRU TD+3 MIN

RESET WATCH
-1:00 MASTER ARM-ON
- :30 ENG ARM-DES
- :07.5 ULLAGE
- :05 PRO
+ :00 PDI
+ :02 (NO IGN) - START PB - PUSH

+ :05 DES ENG OVRD -ON
MASTER ARM-OFF
+0:26 THROTTLE UP
√T/W > 1.6

V21N69

V57E - (+) LR HIGHER THAN LGC PRO TO PERMIT LR DATA

✓ ED BATTS

N68
223+00060 (DO NOT ENTR)

SEQ CAMR - ON

EVAL MAN CONT

θ	TFI	VI	(-ḢMAX) -HDOT	(ΔH) H	DPS	SBD P/Y
110	0:00	5558.5	3.5	51488	100	-2/2
110	0:30	5488.3	5.7	51393	98	
104	1:00	5202.1	26.0	50906	93	2/-2
99	1:30	4907.3	41.6	49880	88	
94	2:00	4604.5	53.3	48449	82	9/-9
90	2:30	4293.7	62.5	46707	77	
86	3:00	3974.7	70.2	44713	72	15/-14
83	3:30	3646.8	77.4	42498	66	
81	4:00	3309.4	84.5	40071	61	19/-18
79	4:30	2961.3	92.4	37143 (+17500)	56	
77	5:00	2601.6	100.4	34544	50	22/-20
74	5:30	2229.1	107.7	(+15200) 29786 (+12500)	45	
72	6:00	1846.1	101.4	26194	39	27/-24
70	6:30	1449.4	85.4 (429.9)	(+10900) 23800 (+9500)	34	
67	7:00	1200.5	125.6	21531	31	31/-27
65	7:30	962.3	(389.0) 158.3 (328.1)	(+7600) 17943 (+ 6000)	28	
62	8:00	722.1	179.7	13209	24	35/-30

P64

223E @ 6K

P64 + 15 SEC:
NO THROTTLE DN
- ABORT

523 ALARM
V58
LDG ANT-HOVER
RESET
WAIT 2 SEC.
PRO

PGNS MODE CONT-
ATT HOLD

P66

X-PNTR-LO MULT

BINGO FUEL
DES QTY LT+1+34

TOUCHDOWN

ENG STOP - PUSH
PRO
MODE CONTROL (BOTH) - AUTO
DES ENG CMD OVRD - OFF
ENG ARM - OFF
413 + 1

RECYCLE PARKER VALVE

H	(Ḣ MAX) -H DOT)	DPS
7000	(228.2) 180.4	21
5000	(186.9) 143.8	19
4000	(163.2) 123.4	19
3000	(136.3) 100.4	18
2000	(104.6) 73.2	17
1000	(63.8) 30.6	15
500	(35.7) 13.5	12
400	(28.7) 12.6	12
300	(21.0) 11.5	11
200	(12.2) 9.6	11

ABORT STAGE - PUSH
ENG ARM - ASC
ENG STOP - RESET
ENG START - PUSH
MODE CONTROL(2)- AUTO

INITIAL CONDITIONS EDIT

**********LM STATE VECTORS**********

	TIME (SEC.)	POSITION (METERS) X	Y	Z	RMAG.	VELOCITY (METERS/SEC.) XDOT	YDOT	ZDOT	VMAG.
AGC =	372491.4799	- 1143902.4	- 1226706.4	- 514312.9	+ 1754527.5	-1269.606	+1080.857	+ 290.767	+1692.542
ENV =	372491.4799	- 1143908.2	- 1226706.4	- 514313.0	+ 1754527.6	-1269.606	+1080.857	+ 290.767	+1692.542
DIFF=-	0.0000	- 0.2	- 0.0	+ 0.0	+ 0.2	+ 0.000	- 0.000	- 0.000	+ 0.000

**********CSM STATE VECTORS**********

	TIME (SEC.)	POSITION (METERS) X	Y	Z	RMAG.	VELOCITY (METERS/SEC.) XDOT	YDOT	ZDOT	VMAG.
AGC =	372491.4799	- 677982.4	- 1005957.4	- 615355.4	+ 1848627.0	-1507.642	+ 603.306	+ 105.199	+1627.277
ENV =	372491.4799	- 677982.6	- 1005957.2	- 615355.3	+ 1848627.0	-1507.642	+ 603.306	+ 105.199	+1627.277
DIFF=-	0.0000	+ 0.1	- 0.2	- 0.1	+ 0.2	+ 0.000	- 0.000	+ 0.000	+ 0.000

**********LINE-OF-SIGHT VECTORS**********

	TIME (SEC.)	POSITION (METERS) X	Y	Z	RMAG.	VELOCITY (METERS/SEC.) XDOT	YDOT	ZDOT	RDOTC
AGC =	372491.4799	+ 465925.0	- 373250.9	- 100542.4	+ 609119.5	- 238.035	- 477.551	- 185.568	+ 145.886
ENV =	372491.4799	+ 465925.6	- 373250.8	- 100542.3	+ 609119.5	- 238.035	- 477.551	- 185.568	+ 145.886
DIFF=-	0.0000	+ 0.3	- 0.1	- 0.1	+ 0.4	+ 0.000	- 0.000	+ 0.000	+ 0.000

**********RELATIVE R AND V EPOCHS**********

ALONG LINE-OF-SIGHT(X), ORTHOGONAL TO ACTIVE/PASSIVE PLANE(Z), AND (Y) ORTHOGONAL TO (X) AND (Z)								
X	Y	Z	RMAG	XDOT	YDOT	ZDOT	VMAG	
+ 0.4	- 0.0	+ 0.1	+ 0.4	- 0.000	- 0.000	- 0.000	+ 0.000	

**********REFSMMAT**********

	-0.955	-0.249	-0.156
REFSMMAT =	-0.067	-0.332	+0.940
	-0.286	+0.909	+0.300
	-0.955	-0.249	-0.156
T =	-0.067	-0.332	+0.940
SI	-0.286	+0.909	+0.300

```
TIME2           2D +  37249148                          +3.72491480 E+ 5
ETLEM           2D +  37249148                          +3.72491480 E+ 5
TETCSM          2D +  37249148                          +3.72491480 E+ 5

INITIAL CONDITIONS


RCVLEM          2D -1.14390826 E+ 6B-27 -               -1.14390826 E+ 6
RCVLEM    +2    2D -1.22670645 E+ 6B-27 R               -1.22670645 E+ 6
RCVLEM    +4    2D -5.14813045 E+ 5B-27  LCON           -5.14813045 E+ 5

RRECTLEM        2D -1.14390826 E+ 6B-27 -               -1.14390826 E+ 6
RRECTLEM  +2    2D -1.22670645 E+ 6B-27 R               -1.22670645 E+ 6
RRECTLEM  +4    2D -5.14813045 E+ 5B-27  LO             -5.14813045 E+ 5

VCVLEM          2D -1.26960674 E+ 1B-05 -               -1.26960674 E+ 3
VCVLEM    +2    2D +1.08085729 E+ 1B-05 V               +1.08085729 E+ 3
VCVLEM    +4    2D +2.90767580 E+ 0B-05  LCON           +2.90767580 E+ 2

VRECTLEM        2D -1.26960674 E+ 1B-05 -               -1.26960674 E+ 3
VRECTLEM  +2    2D +1.08085729 E+ 1B-05 V               +1.08085729 E+ 3
VRECTLEM  +4    2D +2.90767580 E+ 0B-05  LO             +2.90767580 E+ 2

RCVCSM          2D -6.77982641 E+ 5B-27 -               -6.77982641 E+ 5
RCVCSM    +2    2D -1.60595727 E+ 6B-27 R               -1.60595727 E+ 6
RCVCSM    +4    2D -6.15355379 E+ 5B-27  CCON           -6.15355379 E+ 5

RRECTCSM        2D -6.77982641 E+ 5B-27 -               -6.77982641 E+ 5
RRECTCSM  +2    2D -1.60595727 E+ 6B-27 R               -1.60595727 E+ 6
RRECTCSM  +4    2D -6.15355379 E+ 5B-27  CO             -6.15355379 E+ 5

VCVCSM          2D -1.50764261 E+ 1B-05 -               -1.50764261 E+ 3
VCVCSM    +2    2D +6.03306059 E+ 0B-05 V               +6.03306059 E+ 2
VCVCSM    +4    2D +1.05199093 E+ 0B-05  CCON           +1.05199093 E+ 2

VRECTCSM        2D -1.50764261 E+ 1B-05 -               -1.50764261 E+ 3
VRECTCSM  +2    2D +6.03306059 E+ 0B-05 V               +6.03306059 E+ 2
VRECTCSM  +4    2D +1.05199093 E+ 0B-05  CO             +1.05199093 E+ 2
                END     H14PDI
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
                INSERT  H3PADS
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
REATED ON 05/05/70 AT 03'47'34

FLAGWRD3        OCT     10000
FLAGWRD8        OCT     06000
FLGWRD10        OCT     00000
MASS            2D +1.53618127 E+ 4B-16 M               +1.53618127 E+ 4
LEMMASS         1D +1.53618127 E+ 4B-16 M               +1.53618127 E+ 4
CSMMASS  + 0    1D  1.68393445 E+04B-16  3.712440000+004  LBS

DSPTAB +11D     OCT     0
CDUZ            OCT     0

LGC IMU COMPENSATION PARAMETERS

PBIASX          OCT     05503                           2.2 CM/SEC
```

START TIME

BIASY	OCT	72274	-2.2 CM/SEC
BIASZ	OCT	01217	0.5 CM/SEC
PIPASCFX	OCT	10142	5///MILLION
PIPASCFY	OCT	67635	-500 /MILLION
PIPASCFZ	OCT	37746	1950 /MILLION
NBDX	OCT	02371	10 MERU
NBDY	OCT	75406	-10 MERU
NBDZ	OCT	12737	44 MERU
ADIAX	OCT	00606	15 MERU/G
ADIAY	OCT	01212	25 M RU/G
ADIAZ	OCT	13126	220 MERU/G
ADSRAX	OCT	00606	15 MERU/G
ADSRAY	OCT	13126	220MERU/G
ADSRAZ	OCT	77171	-15 MERU/G
GCOMP +0	2DEC	0	
GCOMP +2	2DEC	0	
GCOMP +4	2DEC	0	
GCOMPSW + 0	1D 00000		0.000000000+000

FRA MAURO TERRAIN PROFILE II - DATA BY KRIEGSMAN - ERASABLES BY KLUMPP

ABSC0	1D 72324	
ABSC1	1D -45720.0 B-18	
ABSC2	1D -11276.4 B-18	
ABSC3	1D -4572.00 B-18	
ABSC4	1D -1524.00 B-18	
SLOPE0	1D -.100000 B-06	
SLOPE1	1D -.011905 B-06	
SLOPE2	1D +.055555 B-06	
SLOPE3	1D -.040000 B-06	
SLOPE4	1D -.020000 B-06	

ALIGNMENT OPTICAL TELESCOPE DETENT PADLOADS

AOTAZ	OCT	65252
AOTAZ +1	OCT	00000
AOTAZ +2	OCT	12525
AOTAZ +3	OCT	25252
AOTAZ +4	OCT	40000
AOTAZ +5	OCT	52525
AOTEL	OCT	10000
AOTEL +1	OCT	10000
AOTEL +2	OCT	10000
AOTEL +3	OCT	10000
AOTEL +4	OCT	10000
AOTEL +5	OCT	10000

RENDEZVOUS AND LUNAR SURFACE NAVIGATION INITIALIZATION

WRENDPOS	OCT	05750
WRENDVEL	OCT	00763
WSURFPOS	OCT	02764
WSURFVEL	OCT	00372
WSHAFT	OCT	17270
WTRUN	OCT	17270
THMAX	OCT	00023

```
VMAX            OCT     00001
SE  TVAR        DEC      E-6 B12
TRUNVAR         DEC      E-6 B12
RVARMIN         DEC     66.0 B-12
VVARMIN         DEC     .17445 E-5 B12
RANGEVAR        2DEC*   .11111111 E-4 B12*
RATEVAR         2DEC*   1.877777 E-5 B12*
X789            2DEC    0
X789 +2         2DEC    0
X789 +4         2DEC    0

PADLOADS FOR THE R2 LUNAR GRAVITATIONAL POTENTIAL MODEL

E3J22R2M        OCT     12160
E32C31RM        OCT     03363

MISCELLANEOUS INITIALIZATION

ATIGINC         2DEC    18000
PTIGINC         2DEC    18000
AGSK            OCT     03671
AGSK +1         OCT     21200
TNEWA    + 0    1D 20000
TNEWA    + 1    1D 00000

DKTRAP   + 0    1D -3.88888888 E-03B+03 -3.888888889-003
DK  EGAN + 0    1D  1.00000000 E+01B-14  1.000000000+001
DKKAOSN  + 0    1D  6.00000000 E+01B-14  6.000000000+001
LMTRAP   + 0    1D -3.88888888 E-03B+03 -3.888888889-003
LMOMEGAN + 0    1D  0.00000000 E+00B-14  0.000000000+000
LMKAOSN  + 0    1D  6.00000000 E+01B-14  6.000000000+001
DKDB     + 0    1D  2.56000000 E+02B-15  2.560000000+002

AUTOPILOT INITIALIZATION

ROLLTIME        OCT     05556
PITTIME         OCT     04431
POSTORKP        2DEC    0
POSTORKU        2DEC    0
POSTORKV        2DEC    0

ABORT INITIALIZATION

J1PARM   + 0    2D  1.83969285 E+06B-23  6.035737700+006  FT
K1PARM   + 0    2D -6.12342049 E+05B-23 -3.197416800+005  FT/RAD
J2PARM   + 0    2D  1.84096185 E+06B-23  6.039901100+006  FT
K2PARM   + 0    1D 73337                -6.247310200+005  FT/RAD
K2PARM   + 1    1D 47011
THETCRIT + 0    2D -4.77128789 E-02B+00 -1.717663642+001  DEG
RAMIN    + 0    2D  1.79020009 E+06B-24  5.873359885+006  FT
YL IM    + 0    2D  1.51864000 E+04B-24  8.200000000+000  N.M.
AB  OOT  + 0    2D  5.94360000 E-02B-07  1.950000000+001  FT/SEC
COSTHET1 + 0    2D  0.00000000 E+00B-02  0.000000000+000
COSTHET2 + 0    2D  8.66025403 E-01B-02  8.660254037-001

P12 INITIALIZATION
```

IGNAOSQ	+ 0	1D	1.93333333 E-02B+02	6.960000000+000	DEG/SEC2
IGNAOSR	+ 0	1D	1.55555555 E-03B+02	5.600000000-001	DEG/SEC2
HIASCENT	+ 0	1D	4.94415683 E+03B-16	1.090000000+004	LBS

LANDING SITE DEPENDENT DATA

TLAND		2D + 37347617		TLAND	+3.73476171 E+ 5
RLS		2D +1.65305549 E+ 6B-27		-	+1.65305549 E+ 6
RLS	+2	2D -5.20705500 E+ 5B-27		R	-5.20705500 E+ 5
RLS	+4	2D -1.11122499 E+ 5B-27		LS	-1.11122499 E+ 5
TEPHEM		1D + 3		T (EPOCH	+3.88197999 E+ 6
TEPHEM	+1	2D + 82891632		0 SECS U.T.)	
AXO		2DEC* 3.962911018 E-5*			
-AYO		2DEC* -5.58111439 E-6*			

LUNAR LIBRATION

504LM		2D -.000398466		-	-3.98466794 E- 4
504LM	+2	2D -.000002989		L	-2.98927218 E- 6
504LM	+4	2D -.000379924		LIBRATION	-3.79924699 E- 4

GEOMETRY OF INERTIAL REFERENCE AND PLATFORM COORDINATES

REFSMMAT		2D -.477840406		-	-9.55680812 E- 1
REFSMMAT	+2	2D -.124686983		REFSMMAT	-2.49373967 E- 1
REFSMMAT	+4	2D -.078241307		0	-1.56482615 E- 1
REFSMMAT	+6	2D -.033691028		-	-6.73820565 E- 2
INGREFSMMAT	+10	2D -.166088687		REFSMMAT	-3.32137374 E- 1
INGREFSMMAT	+12	2D +.470410571		3	+9.40821142 E- 1
INGREFSMMAT	+14	2D -.143295013		-	-2.86590026 E- 1
INGREFSMMAT	+16	2D +.454834417		REFSMMAT	+9.09668834 E- 1
INGREFSMMAT	+20	2D +.150306992		6	+3.00613985 E- 1

IGNITION ALGORITHM PARAMETERS

VIGN		2D +1.69022706 E+ 1B-10		VIGG	+1.69022706 E+ 3
RIGNX		2D -4.06516453 E+ 4B-24		RIGXG	-4.06516453 E+ 4
RIGNZ		2D -4.40457183 E+ 5B-24		RIGZG	-4.40457183 E+ 5
KIGNX/B4		2D -.020687499		KX	+3.30999999 E- 1
KIGNY/B8		2D -.126199802		KY	+1.92565616 E- 6
KIGNV/B4		2D -.167083740		KV	+4.38000000 E+ 2

BRAKING AND APPROACH PHASE TARGETS

TCGIBRAK		1D +9.00000000 E+ 4B-17		TCGIBRAK	+9.00000000 E+ 2
TCGFBRAK		1D +3.00000000 E+ 3B-17		TCGFBRAK	+3.00000000 E+ 1
TENDBRAK		1D +6.20000000 E+ 3B-17		TENDBRAK	+6.20000000 E+ 1
GAINBRAK		2D +9.99999998 E- 1B+00		GAINBRAK	+9.99999998 E- 1
RBRFGX		2D -1.08571283 E+ 3B-24		-	-1.08571283 E+ 3
RBRFGZ		2D -4.17750039 E+ 3B-24		OFG	-4.17750039 E+ 3

VBRFGX	2D	-5.69680495 E- 1B-10	-		-5.69680495 E+ 1
VBRFGZ	2D	-3.00954002 E- 1B-10	OFG		-3.00954002 E+ 1
ABRFGX	2D	-1.37236046 E- 5B+04	-		-1.37236046 E- 1
ABRFGZ	2D	-2.90020170 E- 4B+04	OFG		-2.90020170 E+ 0
VBRFG*	2D	-6.77146506 E- 1B-1C	18/8	VOFZG	-6.77146506 E+ 1
ABRFG*	2D	-1.74012102 E- 3B+04	6	AOFZG	-1.74012102 E+ 1
JBRFG*	2D	-3.59485996 E- 8B+18	8	JOFZG	-3.59485996 E- 2
DELTTFAP	1D	-9.00000000 E+ 3B-17	TGOAUG		+9.00000000 E+ 1
TCGIAPPR	1D	+2.00000000 E+ 4B-17	TCGIAPPR		+2.00000000 E+ 2
TCGFAPPR	1D	+6.00000000 E+ 2B-17	TCGFAPPR		+6.00000000 E+ 0
TENDAPPR	1D	+1.20000000 E+ 3B-17	TENDAPPR		+1.20000000 E+ 1
GAINAPPR	2D	+0.00000000 E+ 0B+00	GAINAPPR		+0.00000000 E+ 0
RAPFGX	2D	+2.52763019 E+ 1B-24	-		+2.52763019 E+ 1
RAPFGZ	2D	-6.14492039 E+ 0B-24	1FG		-6.14492039 E+ 0
VAPFGX	2D	-9.72311999 E- 4B-10	-		-9.72311999 E- 2
VAPFGZ	2D	+9.51981839 E- 4B-10	1FG		+9.51981839 E- 2
AAPFGX	2D	+9.13851359 E- 6B+04	-		+9.13851359 E- 2
AAPFGZ	2D	-1.22422919 E- 5B+04	1FG		-1.22422919 E- 1
VAPFG*	2D	+2.14195913 E- 3B-10	18/8	V1FZG	+2.14195913 E- 1
AAPFG*	2D	-7.34537518 E- 5B+04	6	A1FZG	-7.34537518 E- 1
JAPFG*	2D	+9.19164631 E- 8B+18	8	J1FZG	+9.19164631 E- 2
				J1FZG	+1.14895578 E- 2

P66 INITIALIZATION

RODSCALE + 0	1D	3.04800000 E-03B+07	1.000000000+000	FT/SEC	
TAUROD + 0	2D	1.50000000 E+02B-09	1.500000000+000	SEC	
LAG/TAU + 0	2D	4.13333000 E-01B+00	4.133330000-001		
MINFORCE + 0	2D	4.35925718 E-01B-12	9.800000000+002	LBF	
MAXFORCE + 0	2D	2.80237961 E+00B-12	6.300000000+003	LBF	
TAUHZ	1D	05 E+2 B-11			
QHZ	1D	0.4			
AHZLIM	1D	.591 E-4 B+4			
HLROFF	2D	+15.24 B-24			
TOOFEW	1D	00003			
2LATE466	2D	1.5 E+02 B-28			
ZOOMTIME + 0	1D	2.60000000 E+03B-14	2.600000000+001	SEC	
LEADTIME	1D	-2.19999999 E+ 2B-17	LEADTIME		+2.19999999 E+ 0
LOWCRIT	1D	+ 2136	FLO		+2.66226063 E+ 4
HIGHCRIT	1D	+ 2361	FHI		+2.94249859 E+ 4
ELBIAS	DEC	.001			
AZBIAS	DEC	.001			
VELBIAS	2DEC	.02286 B-6			

PADLOADS FOR NOUN 69

DLAND + 0	2D	0.00000000 E+00B-24	0.000000000+000	FT	
DLAND + 2	2D	0.00000000 E+00B-24	0.000000000+000	FT	
DLAND + 4	2D	0.00000000 E+00B-24	0.000000000+000	FT	

ANDING RADAR RADLOADS

```
RPCRTIME  + 0    1D  6.20000000 E+03B-17  6.200000000+001  SEC
RPCRTQSW  + 0    1D -1.00000000 E+00B-01 -1.000000000+000
DELQFIX   + 0    2D  15.2400000 E+01B-24  5.000000000+002  FT
LRWH      + 0    1D  3.50000000 E-01B+00  3.500000000-001
LRWHL            DEC      0.25
LRHMAX    + 0    1D  1.52400000 E+04B-14  5.000000000+004  FT
LRVMAX    + 0    1D  6.09600000 E+00B-07  2.000000000+003  FT/SEC
LRVF      + 0    1D  6.09600000 E-01B-07  2.000000000+002  FT/SEC
LRWVZ     + 0    1D  3.00000000 E-01B+00  3.000000000-001
LRWVY     + 0    1D  3.00000000 E-01B+00  3.000000000-001
LRWVX     + 0    1D  3.00000000 E-01B+00  3.000000000-001
LRWVFZ    + 0    1D  2.00000000 E-01B+00  2.000000000-001
LRWVFY    + 0    1D  2.00000000 E-01B+00  2.000000000-001
LRWVFX    + 0    1D  2.00000000 E-01B+00  2.000000000-001
LRWVFF    + 0    1D  1.00000000 E-01B+00  1.000000000-001
                 END      H3PADS
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
                 INSERT   LSR002
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
TCCSM             2DEC     0
NUVCSM            2DEC     0
NUVCSM +2         2DEC     0
NUVCSM +4         2DEC     0
XKEPCSM           2DEC     0
DELTACSM          2DEC     0
DELTACSM +2       2DEC     0
DELTACSM +4       2DEC     0
TCLEM             2DEC     0
NUVLEM            2DEC     0
NUVLEM +2         2DEC     0
NUVLEM +4         2DEC     0
XKEPLEM           2DEC     0
DELTALEM          2DEC     0
DELTALEM +2       2DEC     0
DELTALEM +4       2DEC     0
                  END      LSR002
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
READACCS          ENVSUM   2
PREREAD           ENVSUM   2
RODCOMP           CFDUMP                                        1.1
SLAP1             ENVMODE  0
                  PICT     DUTYCYCLE
SLAP1             CFDUMP                                       1.3
SLAP1             DUMP     32              END-E7              1.4
R60INIT +2        DUMP     32              END-E7              1.5
READACCS +1       CFDUMP                                       1.1
ENDLLJOB          DUMP     A               E7,1777             1.2
```

CUAC = 25032

CARDS READ BY ASTRONAUT INPUT-PROG 5 :

```
A       PRINT OFF
A       WAIT 12 V 37 E 00 E
A       VERIFY WITHIN 20 MODE 00 THEN WAIT 2 V 48 E
A       IF V 01 N 46 THEN WAIT 1 V 21 E  21112 E WAIT 3 PROCEED
A       IF V 06 N 47 THEN WAIT 1 V 21 E +33380 E WAIT 1 PROCEED
A       IF V 06 N 48 THEN WAIT 1 V 34 E      WAIT 2
A       W 1  LEMRADAR OFF
A       V 37 E 63 E          WAIT 2
A        DISPLAY INERTIAL DATA ON     WAIT 1
A       IF V 06 N 61 THEN WAIT 2 PROCEED WAIT 2
A       IF V 50 N 25 B1 00014 THEN WAIT 2 ENTER WAIT 2
A       IF V 50 N 18 THEN GUIDEMODE PRIMARY SCSMODE AUTO WAIT 2 PROCEED
A       IF V 50 N 18 THEN WAIT 2 ENTER
A       IF V 99 N 62 THEN DCENGARM ON  LEMTHROT 10 WAIT 2 PROCEED
A       WAIT 100  V 57 E  WAIT  10  V 34 E
A       WAIT 30 V 57 E WAIT  25 V 34 E WAIT  1 LEMRADAR OFF WAIT  50 V 57 E W
ATRYIT  VERIFY WITHIN 120  NOABORT V 06 N 68  R3  UNEQ +99999 THEN GO TO LRON
A       OTHERWISE V 34 E  WAIT  10 V 57 E  GO TO  TRYIT  END
ALRON   WAIT 5 PROCEED
A       WAIT  15 PROCEED
        WAIT 15
A       WAIT 25 V 57 E  WAIT 6 PROCEED  WAIT  10  PROCEED
ALROFF  IF V 06 N 64 THEN W 2   PROCEED W 2
A       LRHCRATE 99999 LEMHCTRL R -5 W .03 LRHCRATE 99999 LEMHCTRL R 0 W .5
A       W 15
A       LRHCRATE 99999 LEMHCTRL Q -5 W .03 LRHCRATE 99999 LEMHCTRL Q 0 W .5
A       LRHCRATE 99999 LEMHCTRL Q -5 W .03 LRHCRATE 99999 LEMHCTRL Q 0 W .5
ACONT   S 72 H
A       W 5  V 37 E 68 E
A       IF V 06 N 43 THEN WAIT 2 PROCEED WAIT 2
A       WAIT 5 V 69 E
```

END OF ASTRONAUT INPUT CARDS.

```
LABEL  TRYIT   IS EQN #   292181 .
LABEL  LRON    IS EQN #   292200 .
LABEL  LROFF   IS EQN #   292220 .
LABEL  CONT    IS EQN #   292295 .
```

INPUTPROG INITIALIZATION CARDS:

D		PRDTCTRL	FLIGHT #		ALTT		
000000000	00	0.0	5.04000000000	02	-1.40496414599	03	-3.008

VERSE ROUTINE IS USING DATA FOR THE PERIOD FROM JULY 1, 1970 THROUGH JULY 1971

EVENT LIST (AGC TIME)

TIG = 372791.5

THROTTLE-UP = 372817.5

THROTTLE-DOWN = 373195.

HIGATE = 373298

REDES (-AZ) = 373304.5

REDES (+EL) = 373321.0

REDES (+EL) = 373322.4

LOGATE = 373450.7

TOUCHDOWN = 373496

ADDENDUM to LUMINARY Memo #160

Summary:

A further study of the Descent Trajectory Monitor Package of Luminary Memo #160 led to an all-digital simulation at MIT/DL using a smooth moon in the environment and the LGC; i.e. no terrain model used. This data was compared with the LM Timeline chart of 3/16/70 and the result was found to be that the LM Timeline data corresponds much better with the MIT/DL data without terrain than MIT/DL data with terrain. The H and VI plots are such that the general curve shape is followed nearly coincidental. The HDOT curve follows a general shape pattern nearly parallel with a constant difference of about 8 fps until throttle-recovery, at which time the curves for LM Timeline Data and MIT/DL continue nearly coincidental to the end of the run sample period.

Suggestion:

Communication of Apollo 14 (Luminary 1D) trajectory parameters, using the latest known Fra Mauro terrain parameters, to all simulators so that the Descent Trajectory Monitor chart for a final Apollo 14 LM Timeline Book can be verified from independent observers at MSC, KSC, and MIT/DL.